US009438324B2

(12) United States Patent
Ohm et al.

(10) **Patent No.:** **US 9,438,324 B2**
(45) **Date of Patent:** *Sep. 6, 2016

(54) **METHOD OF ASSIGNING PRECODING VECTORS IN A MOBILE CELLULAR NETWORK**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 106 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/270,638**

(22) Filed: **Oct. 11, 2011**

(65) **Prior Publication Data**

US 2012/0063344 A1 Mar. 15, 2012

Related U.S. Application Data

(63) Continuation of application No. 12/494,756, filed on Jun. 30, 2009, now Pat. No. 8,040,865.

(30) **Foreign Application Priority Data**

Jun. 30, 2008 (EP) 08290631

(51) **Int. Cl.**
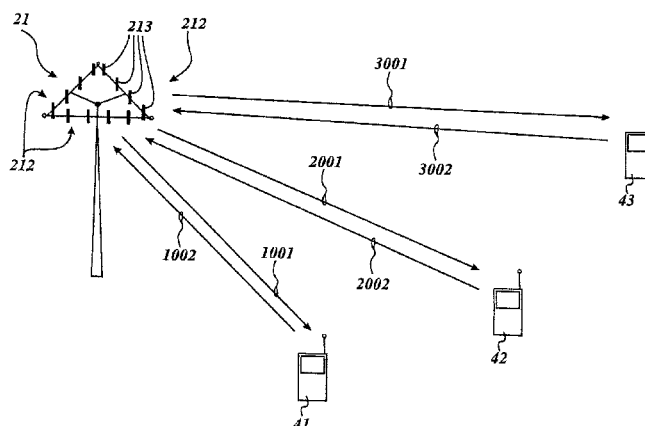*H04W 4/00* (2009.01)
H04B 7/04 (2006.01)
H04B 7/06 (2006.01)

(52) **U.S. Cl.**
CPC *H04B 7/0452* (2013.01); *H04B 7/0417* (2013.01); *H04B 7/0619* (2013.01)

(58) **Field of Classification Search**
CPC H04B 7/0417; H04B 7/0619; H04B 7/0452; H04W 72/02; H04W 24/00

USPC 375/260–265; 455/501; 370/252, 370/329–338
See application file for complete search history.

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(57) **ABSTRACT**

A method for assigning precoding vectors in a mobile cellular network as well as a base station. The base station provides a code book comprising indexed precoding vectors to mobile stations associated with the base station via a downlink channel. A mobile station selects indices of preferred precoding vectors from the code book and reports the indices to the base station via an uplink channel. The mobile selects indices of preferred companion precoding vectors from the code book that shall preferably be used by the base station for other mobile stations served by the base station on the same time/frequency resource, and reports the indices associated with the preferred companion precoding vectors to the base station via the uplink channel. For each mobile station, the base station determines a precoding vector based on the reported indices of the preferred precoding vectors and the reported indices of the preferred companion precoding vectors.

19 Claims, 2 Drawing Sheets

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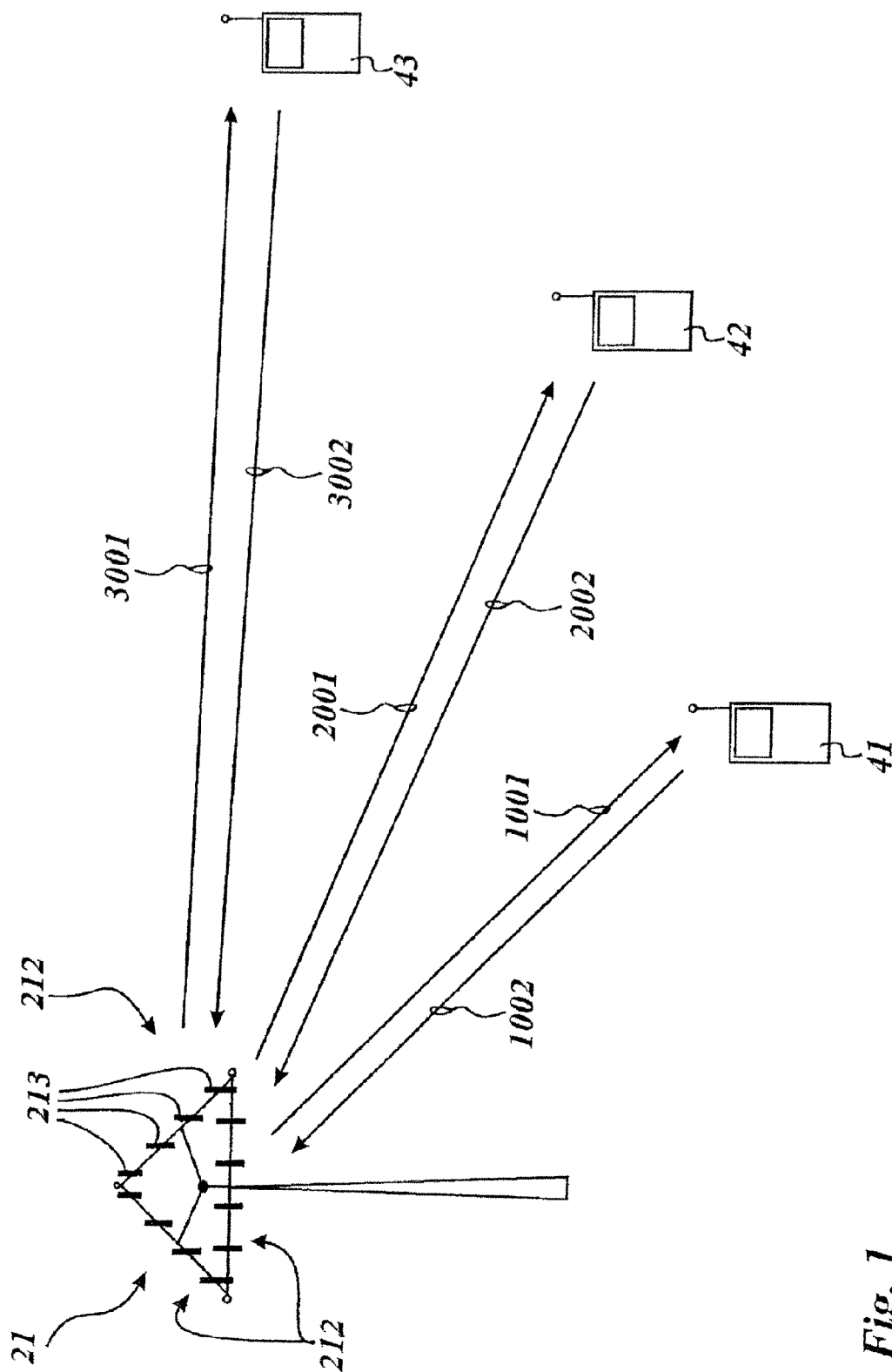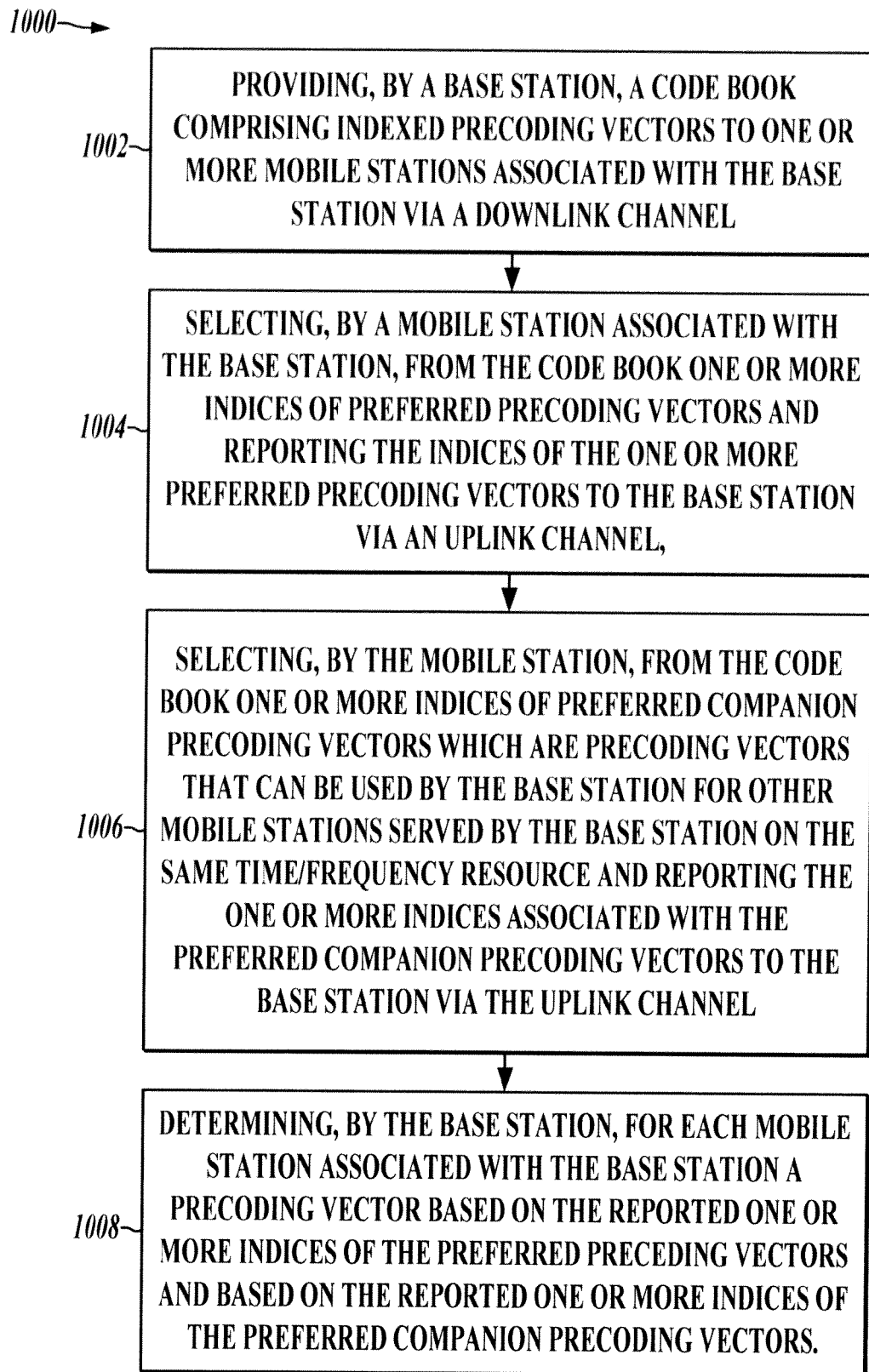
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Fig. 1

1000⟶

1002~ PROVIDING, BY A BASE STATION, A CODE BOOK COMPRISING INDEXED PRECODING VECTORS TO ONE OR MORE MOBILE STATIONS ASSOCIATED WITH THE BASE STATION VIA A DOWNLINK CHANNEL

1004~ SELECTING, BY A MOBILE STATION ASSOCIATED WITH THE BASE STATION, FROM THE CODE BOOK ONE OR MORE INDICES OF PREFERRED PRECODING VECTORS AND REPORTING THE INDICES OF THE ONE OR MORE PREFERRED PRECODING VECTORS TO THE BASE STATION VIA AN UPLINK CHANNEL,

1006~ SELECTING, BY THE MOBILE STATION, FROM THE CODE BOOK ONE OR MORE INDICES OF PREFERRED COMPANION PRECODING VECTORS WHICH ARE PRECODING VECTORS THAT CAN BE USED BY THE BASE STATION FOR OTHER MOBILE STATIONS SERVED BY THE BASE STATION ON THE SAME TIME/FREQUENCY RESOURCE AND REPORTING THE ONE OR MORE INDICES ASSOCIATED WITH THE PREFERRED COMPANION PRECODING VECTORS TO THE BASE STATION VIA THE UPLINK CHANNEL

1008~ DETERMINING, BY THE BASE STATION, FOR EACH MOBILE STATION ASSOCIATED WITH THE BASE STATION A PRECODING VECTOR BASED ON THE REPORTED ONE OR MORE INDICES OF THE PREFERRED PRECEDING VECTORS AND BASED ON THE REPORTED ONE OR MORE INDICES OF THE PREFERRED COMPANION PRECODING VECTORS.

Fig. 2

METHOD OF ASSIGNING PRECODING VECTORS IN A MOBILE CELLULAR NETWORK

REFERENCE TO RELATED APPLICATIONS

This application is a continuation of, and claims priority to and the benefit of, U.S. patent application Ser. No. 12/494,756, filed on Jun. 30, 2009, entitled METHOD OF ASSIGNING PRECODING VECTORS IN A MOBILE CELLULAR NETWORK, and this application claims priority to application EP08290631.4, filed Jun. 30, 2008, the entireties of which applications are hereby incorporated by reference.

BACKGROUND

The present disclosure relates to a method of and a base station for assigning precoding vectors in a mobile cellular network and to a mobile station.

The technical field of the present disclosure is directed to cellular systems or wireless data systems, in which a base station (BS=base station) serves a number of mobile stations (MS=mobile station) on the same time/frequency resources by means of a MU-MIMO system (MU=multiple user, MIMO=multiple input multiple output). The MU-MIMO system is a system wherein a base station comprises $N \geq 2$ transmit antennas and serves a number of mobile stations on the same time/frequency resources. In order to allow each mobile station to receive only data streams intended for the mobile station, the base station has to apply certain antenna weights, also called precoding vectors, to the data streams that the base station transmits to the mobile stations.

In order to select the precoding vectors properly, the base station needs to have some channel state information. In TDD systems (TDD=time-division duplex), this channel state information can be obtained by uplink channel sounding because of the reciprocity of the uplink and downlink channels. In FDD systems (FDD=frequency-division duplex), however, this reciprocity is not available and can thus not be used. There is a need to define a fixed or preset set of precoding vectors. The set of precoding vectors is called code book. The code book is known to both the base station and mobile station. The mobile station selects a precoding vector that maximizes or minimizes some metric defining a signal quality parameter in order to improve its received signal quality. However, it is possible that a high intra-cell spatial interference still exists.

SUMMARY

It is the object of the present disclosure to provide an improved assignment of precoding vectors in a mobile cellular network.

The object of the present disclosure is achieved by a method of assigning precoding vectors in a mobile cellular network, wherein a base station provides a code book comprising indexed precoding vectors to one or more mobile stations associated with the base station via a downlink channel, a mobile station associated with the base station selects from the code book one or more indices of preferred precoding vectors and reports the indices of the one or more preferred precoding vectors to the base station via an uplink channel, the mobile station selects from the code book one or more indices of preferred companion precoding vectors which are precoding vectors that shall preferably be used by the base station for other mobile

stations served by the base station on the same time/frequency resource and reports the one or more indices associated with the preferred companion precoding vectors to the base station via the uplink channel, and the base station determines for each mobile station associated with the base station a precoding vector based on the reported one or more indices of the preferred precoding vectors and based on the reported one or more indices of the preferred companion precoding vectors. The object of the present disclosure is also achieved by a base station in a mobile cellular network, wherein the base station comprises a control unit for assigning precoding vectors, whereby the control unit provides a code book comprising indexed precoding vectors to one or more mobile stations associated with the base station via a downlink channel, the control unit receives one or more indices of preferred precoding vectors selected from the code book from each of the one or more mobile station associated with the base station via an uplink channel, the control unit receives one or more indices of preferred companion precoding vectors selected from the code book from each of the one or more mobile units via the uplink channel, the preferred companion precoding vectors are precoding vectors that shall preferably be used by the base station for other mobile stations served by the base station on the same time/frequency resource and the control unit determines for each mobile station associated with the base station a precoding vector based on the reported one or more indices of the preferred precoding vectors and based on the reported one or more indices of the preferred companion precoding vectors.

The present disclosure provides an effective method for reducing intra-cell spatial interference. In practice, only the mobile station has complete channel information. Therefore, the base station can only estimate signal quality parameters, such as the signal-to-noise-and-interference-ratio. However, the mobile station is able to measure or calculate a suitable signal quality parameter. The conventional selection of precoding vectors for and assignment to mobile stations by the base station is based on preferred precoding vectors of the mobile stations only and it is not taken into account that the transmission to one mobile station with its preferred precoding vector also creates interference for all other mobile stations served on the same time/frequency resources. The present disclosure removes this disadvantage, since the mobile station provides information of other mobile stations to the base station by means of the preferred companion precoding vectors. The base station of the present disclosure is able to assign precoding vectors to its associated mobile stations which are mutually exclusive. Mutually exclusive preferably means that a precoding vector assigned to a first mobile station is a preferred companion precoding vector of another mobile station served by the same base station and vice versa. Therefore, not only the signal quality at the mobile station is improved, but also the communication bandwidth provided by the base station to each of its associated mobile stations. Consequently, transmission errors between the base station and the mobile station are reduced and the data throughput is increased. Moreover, by means of exchanging precoding vector indices between the base station and the mobile station only, the amount of signaling overhead is reduced. A reduced amount of signaling traffic between the base station and the mobile station reduces further intra-cell spatial interference.

Further advantages are achieved by embodiments of the present disclosure indicated by the dependent claims.

According to a preferred embodiment of the present disclosure, the mobile station calculates a signal quality

parameter for each precoding vector of the code book or a subset of the precoding vectors of the code book. In particular, the signal quality parameter is a real scalar inter-cell interference indicator indicating a inter-cell spatial interference, a intra-cell spatial interference, a received signal strength, a signal-to-noise-ratio, and/or a signal-to-interference-and-noise-ratio. A real scalar inter-cell interference indicator is a real number which can be easily compared with other real numbers of the same type by means of relations, in particular "less than", "greater than", and/or "equal to". Therefore, an evaluation criterion for the pre-coding vectors exists, which can be used during the selection process of preferred precoding vectors and preferred companion precoding vectors. The mobile station selects the indices of the preferred precoding vectors and preferred companion precoding vectors based on the calculated signal quality parameters.

According to a preferred embodiment of the present disclosure, the base station applies to the antennas of the base station a sequence of reference signals. Each mobile station of the one or more mobile stations associated with the base station measures the reference signals of said sequence of reference signals and calculates the signal quality parameters based on said measurement.

It is possible, that the reference signals are dedicated pilot signals, i.e. the reference signals are associated with pre-coding vectors contained in the code book.

Preferably, the base station informs one or more mobile stations associated with the base station about the sequence of dedicated reference signals associated with precoding vectors contained in the code book to be applied to an antenna of the base station. This information can be signaled, preferably by means of specific signaling messages, from the base station to the mobile stations via the downlink channel.

It is also possible, that the reference signals are common reference signals, i.e. reference signals which are not associated with precoding vectors.

The calculation of the signal quality parameters is performed under the assumption that the base station uses the precoding vectors from the known code book for the data transmission. Preferably, based on said measurement, the mobile station calculates a received signal strength, a signal-to-noise-ratio, a signal-to-interference-and-noise-ratio, and/or intra-cell spatial interference indicator. In case, that the reference signals are common pilot signals, each mobile station of the one or more mobile stations calculates the signal quality parameters based on said measurement and the precoding vectors, wherein preferably one or more reference signals of the sequence of reference signals are multiplied by the respective precoding vector.

Furthermore, it is possible to represent said calculated signal quality parameters based on said measurement as a function of the precoding vector index. The extrema of said function are related to preferred precoding vector indices and preferred companion precoding vector indices. For instance, in case the calculated signal quality parameter is a received signal strength, a signal-to-noise-ratio or a signal-to-interference-and-noise-ratio, then indices close to the regions of the minima of said function are designated as preferred companion precoding vector indices and indices close to the regions of the maxima of said function are designated as preferred precoding vector indices.

According to a preferred embodiment of the present disclosure, the mobile station selects the one or more indices of preferred precoding vectors and the one or more indices of preferred companion precoding vectors based on the

calculated signal quality parameters. Preferably, the selection process is performed as above described by means of a respective function indicating a signal quality parameter depending on the precoding vector index. The one or more preferred precoding vectors show a high or a maximum received signal strength, signal-to-noise-ratio and/or signal-to-interference-and-noise-ratio. In contrast to that, the one or more preferred companion precoding vectors show a low or a minimum received signal strength, signal-to-noise-ratio and/or signal-to-interference-and-noise-ratio.

According to a preferred embodiment of the present disclosure, the mobile station selects an index of one preferred precoding vector and one or more indices of auxiliary preferred precoding vectors which are reported to the base station via an uplink channel. The auxiliary precoding vector is an alternative to the preferred precoding vector if the preferred precoding vector cannot be assigned as determined precoding vector to the respective mobile station. By means of introducing auxiliary precoding vectors it is possible to assign different precoding vectors to two different mobile stations, even if these two mobile stations have reported the same preferred precoding vector index to the base station.

According to a preferred embodiment of the present disclosure, the mobile station reports the calculated signal quality parameters assigned to the one or more preferred companion precoding vectors to the base station. Then, the base station determines the precoding vectors for the mobile stations based on said signal quality parameters assigned to the one or more preferred companion precoding vectors. The base station can optimize across its associated mobile stations the overall signal quality based on the additional information of signal quality parameters assigned to the one or more preferred companion precoding vectors provided by the mobile station.

According to a preferred embodiment of the present disclosure, the base station informs one or more mobile stations associated with the base station about a respective threshold of a signal quality parameter which is acceptable for a precoding vector to be selected as preferred companion precoding vectors at the respective mobile station. A respective mobile station calculates the signal quality parameters for two or more, preferably all, precoding vectors of the code book. The respective mobile station compares the calculated signal quality parameters with the threshold. The respective mobile station selects the index or indices of that precoding vectors as preferred companion precoding vectors which comply with the threshold. A threshold value provides a level of minimum acceptance of a preferred companion precoding vector. A preferred companion precoding vector not satisfying said threshold and used as preferred companion precoding vector, i.e. as precoding vector of another mobile station, will significantly degrade the signal quality at the mobile station.

According to a preferred embodiment of the present disclosure, the mobile station selects only those precoding vectors as preferred companion precoding vectors which produce in combination with a preferred precoding vector an intra-cell spatial interference remaining below a predefined threshold. Instead of the intra-cell spatial interference, it is also possible to use a received signal strength, a signal-to-noise-ratio or a signal-to-interference-and-noise-ratio which will be enhanced.

According to a preferred embodiment of the present disclosure, the base station informs a mobile station of the one or more mobile stations associated with the base station about a preset number of indices of preferred companion precoding vectors. The mobile station selects the preset

number of indices of preferred companion precoding vectors. In cases in which a preset number of indices of preferred companion is used, the number of indices of preferred companion precoding vectors is not required in the uplink feedback and therefore reduces the administrative signaling between the mobile station and the base station. Furthermore, a preset number of indices of preferred companion precoding vectors simplifies the administration of preferred companion precoding vector indices associated with their respective mobile station at the base station.

According to a preferred embodiment of the present disclosure, the base station determines the precoding vectors for the mobile stations so that a precoding vector index of the mobile station is a preferred companion precoding vector index of another mobile station for a maximum number of the mobile stations. For example, the base station uses the received indices as input parameter of an optimization algorithm, e.g. an exhaustive search algorithm, which finds out an assignment of precoding vectors to mobile stations that fulfills the aforementioned condition.

Preferably, in order to provide intra-cell spatial interference reduction to a maximum number of mobile stations associated with the base station, the base station pairs or combines each index of the reported one or more indices of the preferred precoding vectors with one index of the reported one or more indices of the preferred companion precoding vectors. Each index of the reported one or more indices of the preferred precoding vectors associated with one of the mobile stations of said maximum number of mobile stations is paired with one index of the reported one or more indices of the preferred companion precoding vectors associated with another mobile station of said maximum number of mobile stations.

It is possible that each mobile station associated with the base station chooses only one or more indices of the one or more indices of the preferred companion precoding vectors if the chosen one or more preferred companion precoding vectors associated with the selected one or more indices have a signal quality parameter below a threshold and each mobile station reports the chosen one or more indices as the selected one or more indices associated with the preferred companion precoding vectors to the base station via the uplink channel.

BRIEF DESCRIPTION OF THE DRAWINGS

These, as well as further features and advantages of the disclosure will be better appreciated by reading the following detailed description of presently preferred embodiments taken with the accompanying drawing of:

FIG. 1 shows view of a base station with an antenna providing communication to three mobile stations; and

FIG. 2 shows a flow diagram illustrating an exemplary method of assigning precoding vectors in a mobile cellular network.

DETAILED DESCRIPTION

FIG. 1 shows a base station 21 and three mobile stations 41, 42, 43 in a cell of a mobile cellular network. The base station 21 comprises an antenna. The antenna comprises three antenna units 212, wherein each antenna unit 212 is assigned to a different sector of the cell. Each antenna unit 212 is formed of a linear antenna array with four equal linear antenna elements 213 arranged in parallel. It is also possible, that the antenna unit 212 of the base station 21 has any other antenna configuration, e.g. horizontally or vertically polar-

ized antenna elements 213 or cross-polarized antenna elements, whereby preferably two antenna elements arranged at +45° and two antenna elements arranged at −45°. A control unit of the base station 21 can apply different precoding vectors to each antenna array of the base station 21 separately, in order to control beam forming. A beam is defined by its associated precoding vector. However, beam forming is a special case of linear precoding. In particular, for correlated antenna arrays, e.g. lambda/2 spaced linear arrays, precoding results in beam forming; for uncorrelated antennas, e.g. 10 lambda spaced antenna arrays, no distinct beams are formed. The invented solution works with both correlated and uncorrelated antenna arrays. A precoding vector is a complex vector defining a complex antenna weight for each linear antenna element 213. Preferably, the absolute value of the antenna weight equals 1 and thereby only defines a phase factor. It is also possible to define the amplitude when the absolute value of the antenna weight does not equal 1. Furthermore, the control unit of the base station 21 is composed of software and hardware means, i.e. one or more data processing units, a software platform and one or more application programs running on that system platform, adapted to execute the assignment of precoding vectors in a mobile cellular network.

The control unit of the base station 21 is adapted to control the beam forming of the antenna unit 212 and to provide communication functionality for the base station 21 with other base stations of the cellular mobile network and/or the mobile stations 41, 42, 43. Base stations of the cellular mobile network communicate with other base stations via fixed communication lines of a core network. The base station 21 of the cellular mobile network provides wireless access to the mobile stations 41, 42, 43 located in the cellular mobile network. In order to access the base station 21 wirelessly, each mobile station 41, 42, 43 comprises a control unit, an antenna, and a RF (RF=radio frequency) communication unit feeding the antenna. It is possible, that the antenna of each mobile station 41, 42, 43 comprises one or more antenna units. The control unit of each mobile station 41, 42, 43 controls the antenna of each mobile station 41, 42, 43 and provides wireless communication functionality for the mobile station 41, 42, 43. Furthermore, the control unit of each mobile station 41, 42, 43 provides functionality for calculating and/or measuring signal quality parameters, such as SIR (SIR=signal-to-interference-ratio), SNR (SNR=signal-to-noise-ratio), SINR (SINR=signal-to-interference- and noise-ratio), and/or received signal strength. The control unit of each mobile station 41, 42, 43 also provides functionality for sending, receiving and/or transmitting signals providing wireless communication between the mobile stations 41, 42, 43. Furthermore, the control unit of each mobile station 41, 42, 43 provides functionality for sending, receiving and/or transmitting signals of the calculated and/or measured signal quality parameters.

In a preferred embodiment of the disclosure, the base station 21 transmits information to its associated mobile stations 41, 42, and 43 via downlink channels 1001, 2001, and 3001, respectively. The mobile stations 41, 42, and 43, which are associated with the base station 21, transmit information to their base station 21 via uplink channels 1002, 2002, and 3002, respectively. The downlink channels 1001, 2001, 3001 are frequency-separated from the uplink channels 1002, 2002, 3002.

Preferably, the base station 21 and the mobile stations 41, 42 and 43 are components of a MU-MIMO system.

For instance, the base station **21** has $N \geq 2$ transmit antenna units, which serves a number of K mobile stations **41**, **42**, **43**. Each mobile station **41**, **42**, **43** i, $i=1, \ldots, K$ comprises $M_i \geq 1$ receive antenna units, also called antenna units. For transmitting data on a certain time/frequency resource, the base station **21** selects a group of mobile stations **41**, **42**, **43** from all K available mobile stations. Without loss of generality, it is assumed that the mobile stations **41**, **42**, **43** j, $j \sim 1, \ldots, L$, $L \leq N$ are selected. It is further assumed, that, in the present case, each mobile station **41**, **42**, **43** comprises only one antenna unit as receive antenna, i.e., $M_i = M = 1$. The base station **21** transmits one data stream s_j to each mobile station **41**, **42**, **43**. In order to allow each mobile station **41**, **42**, **43** j to receive only the data stream s_j intended for it, the base station **21** applies certain antenna weights, defined by the precoding vectors, to the data streams the base station **21** sends out. The vector t of the transmitted signals from the N base station antenna units can be written in matrix notation as

$$
t = \begin{pmatrix} t_1 \\ t_2 \\ \vdots \\ t_N \end{pmatrix} = \underbrace{\begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1L} \\ p_{21} & p_{22} & \cdots & p_{2L} \\ \vdots & \vdots & \ddots & \vdots \\ p_{N1} & p_{N2} & \cdots & p_{NL} \end{pmatrix}}_{\substack{(p_1 \ p_2 \ \cdots \ p_L) \\ P}} \cdot \underbrace{\begin{pmatrix} s_1 \\ s_2 \\ \vdots \\ s_L \end{pmatrix}}_{s},
$$

with the vector of data streams s, the antenna weights, i.e. the precoding column vectors, p_j, $j=1, \ldots, L$ which define a precoding matrix P. The received signal at the mobile station **41**, **42**, **43** j is

$$
r_1^{(j)} = h_1^{(j)} t + n_1^{(j)} = (h_{11}^{(j)} h_{12}^{(j)} \ldots h_{1n}^{(j)}) \cdot t + n_1^{(j)},
$$

with the channel vector $h_1^{(j)}$ describing the channels between the N antenna units of the base station **21** and the mobile station's receive antenna unit. $n_1^{(j)}$ is an additive noise and inter-cell interference term. The received signal at the mobile station **41**, **42**, **43** can be rewritten as

$$
r_1^{(j)} = h_1^{(j)} \cdot t + n_1^{(j)} = h_1^{(j)} \cdot (p_1 p_2 \ldots p_L) \cdot s + n_1^{(j)}
$$

$$
r_1^{(j)} = (h_1^{(j)} \cdot p_1 h_1^{(j)} \cdot p_2 \ldots h_1^{(j)} \cdot p_L) \cdot s + n_1^{(j)}.
$$

The term $h_1^{(j)} \cdot p_j \cdot s_j$ describes the signal for the mobile station **41**, **42**, **43** j, and the term

$$
\sum_{n=1, n \neq j}^{L} h_1^{(j)} \cdot p_n \cdot s_n
$$

describes the spatial intra-cell (multi-user) interference observed by the mobile station **41**, **42**, **43** j.

In order to allow the mobile station **41**, **42**, **43** j to properly receive its data stream s_j, the base station **21** selects the precoding vectors in such a way that the spatial interference is kept at an acceptable level with respect to the desired signal. Examples are:

$$
h_1^{(j)} \cdot p_j \cdot s_j \gg \sum_{n=1, n \neq j}^{L} h_1^{(j)} \cdot p_n \cdot s_n,
$$

or, more stringent,

$$
\begin{cases} h_1^{(j)} \cdot p_j \neq 0 \\ \sum_{n=1, n \neq j}^{L} h_1^{(j)} \cdot p_n \cdot s_n = 0 \end{cases}.
$$

This selection at the base station **21** is performed in such a way that the above conditions are fulfilled for all L selected mobile stations. It is possible to include the two given criteria and in particular the actual data streams s_j, $j=1, \ldots, L$ into the selection process. It is also possible to include some function of the terms $h_1^{(j)} \cdot p_n$, $n=1, \ldots, L$, $n \neq j$ into the selection process, which can be used as a measure for the spatial interference, preferably with the mean power of s_j as a parameter.

In practice, the base station **21** requires channel state information in order to select the precoding vectors properly. In a time-division duplex (TDD) systems, this channel state information can be obtained by uplink channel sounding because of the reciprocity of the uplink channels and downlink channels. In frequency-division duplex (FDD) systems, however, this reciprocity is not available and can thus not be used. It is therefore common to define a fixed or a preset set of precoding vectors, i.e. the code book, known to both the base station **21** and mobile station **41**, **42**, **43**, from which the mobile station **41**, **42**, **43** selects the vector that maximizes or minimizes some metric, e.g. the received signal power or the signal-to-noise-and-interference-ratio. Then, only the preferred precoding vector index (PVI=precoding vector index) needs to be signaled back to the base station **21**.

The following can be done in order to improve the selection process and the assignment of precoding vectors of the base station **21** to its associate mobile station **41**, **42**, **43** for transmitting on the same time/frequency resources without knowledge of the full channel vector/matrix for each mobile station **41**, **42**, **43**:

The mobile stations **41**, **42**, **43** do not only report their preferred PVIs (PVI=precoding vector index) via the uplink feedback, but also reports the indices of preferred CPVI (CPVI=companion precoding vector index), i.e. precoding vectors that produce a very low or at least an acceptable spatial interference at the mobile station **41**, **42**, **43**. The base station **21** selects the mobile stations **41**, **42**, **43**, i.e. its associated preferred PVIs, in such a way that the preferred PVIs are mutually exclusive. At the same time, the preferred PVIs of each mobile station are within the set of preferred CPVI of all other selected mobile stations or at least the preferred PVIs of each mobile station are within the set of preferred CPVI of a large number of other selected mobile stations.

For reporting of the preferred CPVIs, each mobile station **41**, **42**, **43** reports to the base station **21** at least one preferred CPVI or a preset or a fixed number of preferred CPVIs. The preferred CPVI corresponds to the precoding vector, which minimizes the intra-cell spatial interference.

In case the spatial interference remains below some threshold, e.g. a threshold value of the SINR at the mobile station, for each additional corresponding precoding vector, a mobile station **41**, **42**, **43** can report more than one preferred CPVI. However, a threshold value is not applicable if a fixed and/or preset number of preferred CPVIs is reported to the base station **21**. The threshold value can

either be the same value as the value of the first preferred CPVI, or it is a higher value than the value of the first preferred CPVI.

It is obvious that the meaning of the relation "larger", "above" etc. is depending on the type of metric and has to be exchanged with "small", "below" etc. depending on the metric. For instance, if the metric is related directly to interference, at the mobile station **41**, **42**, **43**, acceptable CPVIs provide interference, which is lower than a threshold value indicating an acceptable level of interference. However, the opposite is the case when the metric is related indirectly to the interference, i.e. then, acceptable CPVIs provide a respective value exceeding the threshold value.

Preferably, in case more than one preferred CPVI is reported, the preferred CPVIs are reported in ascending order, i.e. first the preferred CPVI for which the corresponding precoding vector results in the lowest spatial interference and last the preferred CPVI for which the corresponding precoding vector results in the highest spatial interference. In addition to the preferred CPVIs, the mobile station **41**, **42**, **43** can also report the corresponding amount of spatial interference by e.g. some scalar spatial interference indicator value or any other suitable scalar real value based on a metric indicating a signal quality.

Preferably, the maximum number of reported preferred CPVIs can be configured by the base station **21** in a dynamic, semi-static, or static way by means of signaling the maximum number of reported preferred CPVIs via the downlink channel **1001**, **2001**, **3001** to the mobile station **41**, **42**, **43**. Said maximum number of reported preferred CPVIs can be individually specified for each mobile station **41**, **42**, **43**.

Preferably, a threshold for additional preferred CPVIs with respect to the threshold value for the first preferred CPVI is configured by the base station **21** in a dynamic, semi-static, or static way and signaled to the mobile stations **41**, **42**, **43** via the downlink channel **1001**, **2001**, **3001**. Said threshold for additional preferred CPVIs with respect to the value for the first preferred CPVI can be individually specified for each mobile station **41**, **42**, **43**.

Furthermore, it is possible that the base station **21** orders the indices of the precoding vectors in such a way that similar precoding vectors are indexed with a similar index, wherein the index is preferably a number. For instance, the code book comprises six precoding vectors p_i with index i=1, 2, 3, 4, 5 or 6. The respective precoding vectors may define beam forms which can be generated by the antennas of the base station **21**. These six precoding vectors are ordered such that the absolute difference of two of the indices i=1, 2, 3, 4, 5 or 6 is indirectly related to an amount of intra-cell spatial interference. For example, the mobile station **41** reports the precoding vector p_1 as preferred precoding vector, and the precoding vectors p_4 and p_6 as preferred companion precoding vectors; the mobile station **42** reports the precoding vector p_4 as preferred precoding vector, and the precoding vectors p_1 and p_6 as preferred companion precoding vectors; and the mobile station **43** reports the precoding vector p_6 as preferred precoding vector, and the precoding vectors p_1 and p_4 as preferred companion precoding vectors. In such a case, the base station **21** will assign the precoding vector p_1 to the mobile station **41**, the precoding vector p_4 to the mobile station **42**, and the precoding vector p_6 to the mobile station **41**. In this case, it is possible to define a threshold value for companion precoding vectors with a minimum absolute difference of indices |i−j|, e.g. |i−j| equals 2.

Referring also to FIG. **2**, a flow diagram illustrates an exemplary method **1000** of assigning precoding vectors in a mobile cellular network. A base station provides a code book at **1002** comprising indexed precoding vectors to one or more mobile stations associated with the base station via a downlink channel. At **1004**, a mobile station associated with the base station selects from the code book one or more indices of preferred precoding vectors and reports the indices of the one or more preferred precoding vectors to the base station via an uplink channel. At **1006**, the mobile station selects one or more indices of preferred companion precoding vectors from the code book which are precoding vectors that can be used by the base station for other mobile stations served by the base station on the same time/frequency resource. At **1006**, the mobile station also reports the one or more indices associated with the preferred companion precoding vectors to the base station via the uplink channel. At **1008**, the base station determines for each mobile station associated with the base station a precoding vector based on the reported one or more indices of the preferred precoding vectors and based on the reported one or more indices of the preferred companion precoding vectors.

The invention claimed is:

1. A mobile station, comprising:
an electronic memory; and
at least one processor coupled with the electronic memory and operable to: select from a code book comprising indexed precoding vectors one or more indices of at least one preferred precoding vector,
select from the code book one or more indices of at least one preferred companion precoding vector which can be used by a base station for other mobile stations served by the base station on the same time/frequency resource,
transmit the one or more indices of the at least one preferred precoding vector towards the base station via an uplink channel,
transmit the one or more indices associated with the at least one preferred companion precoding vector towards the base station via the uplink channel,
determine a signal quality parameter for at least two precoding vectors, wherein the signal quality parameter is a real scalar inter-cell interference indicator indicating an inter-cell spatial interference, a real scalar inter-cell interference indicator indicating a received inter-cell signal strength, a real scalar inter-cell interference indicator indicating an inter-cell signal-to-noise-ratio or a real scalar inter-cell interference indicator indicating an inter-cell signal-to-interference-and-noise-ratio,
select an index of the preferred precoding vector based on the determined signal quality parameter and showing a high received signal strength, signal-to-noise-ratio and/or signal-to-interference-and-noise-ratio, and
select an index of the preferred companion precoding vector based on the determined signal quality parameter and showing a low received signal strength, signal-to-noise-ratio, signal-to-interference-and-noise-ratio and/or inter-cell spatial interference; and
wherein the mobile station is operable to select only those precoding vectors as preferred companion precoding vectors which produce in combination with a preferred precoding vector an intra-cell spatial interference remaining below a predefined threshold.

2. The mobile station according to claim **1**, wherein the at least one processor is operable to determine the signal quality based on a measurement of a reference signal.

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3. The mobile station according to claim **1**, wherein the mobile station is operable to select the index of the preferred precoding vector and at least one index of an auxiliary preferred precoding vector which is reportable to the base station via an uplink channel, wherein the auxiliary precoding vector is an alternative to the preferred precoding vector if the preferred precoding vector cannot be assigned as determined precoding vector to the mobile station.

4. The mobile station according to claim **1**, wherein the mobile station is operable to report the determined signal quality parameters assigned to the one or more preferred companion precoding vectors towards the base station.

5. The mobile station according to claim **1**, wherein the mobile station is operable to: receive information about a respective threshold of the signal quality parameter which is acceptable for a precoding vector to be selected as preferred companion precoding vector at the mobile station, compare the determined signal quality parameters with the threshold, and select the index or indices of that precoding vectors as preferred companion precoding vector indices which are below the threshold.

6. The mobile station according to claim **1**, wherein the mobile station is operable to select precoding vectors from a fixed or a preset set of indexed precoding vectors for the code book, known to the mobile station.

7. A mobile station, comprising:

an electronic memory; and at least one processor coupled with the electronic memory and operable to: determine a signal quality parameter for at least two precoding vectors, in particular a real scalar inter-cell interference indicator indicating an inter-cell spatial interference, a received signal strength, a signal-to-noise-ratio or a signal-to-interference- and-noise-ratio,

select an index of a preferred precoding vector based on the determined signal quality parameter and showing a high received signal strength, signal-to-noise-ratio and/ or signal-to-interference-and-noise-ratio,

select an index of a preferred companion precoding vector based on the determined signal quality parameter and showing a low received signal strength, signal-to-noise-ratio, signal-to-interference-and-noise-ratio and/ or inter-cell spatial interference,

receive information about a respective threshold of the signal quality parameter which is acceptable for a precoding vector to be selected as preferred companion precoding vector at the mobile station,

compare the determined signal quality parameters with the threshold,

select the index or indices of that precoding vectors as preferred companion precoding vector indices which are below the threshold, and

select only those precoding vectors as preferred companion precoding vectors which produce in combination with a preferred precoding vector an intra-cell spatial interference remaining below a predefined threshold.

8. The mobile station according to claim **7**, wherein the at least one processor is operable to determine the signal quality based on a measurement of a reference signal.

9. The mobile station according to claim **7**, wherein the mobile station is operable to select the index of the preferred precoding vector and at least one index of an auxiliary preferred precoding vector which is reportable to the base station via an uplink channel, wherein the auxiliary precoding vector is an alternative to the preferred precoding vector if the preferred precoding vector cannot be assigned as determined precoding vector to the mobile station.

10. The mobile station according to claim **7**, wherein the mobile station is operable to: transmit the one or more indices of the at least one preferred precoding vector towards the base station via an uplink channel, and transmit the one or more indices associated with the at least one preferred companion precoding vector towards the base station via the uplink channel.

11. The mobile station according to claim **7**, wherein the mobile station is operable to report the determined signal quality parameters assigned to the one or more preferred companion precoding vectors towards the base station.

12. The mobile station according to claim **7**, wherein the mobile station is operable to select precoding vectors from a fixed or a preset set of indexed precoding vectors for the code book, known to the mobile station.

13. A mobile station, comprising:

an electronic memory; and

at least one processor coupled with the electronic memory and operable to: select from a code book comprising indexed precoding vectors one or more indices of at least one preferred precoding vector which can be used by a base station for the mobile station,

select from the code book one or more indices of at least one preferred companion precoding vector which can be used by a base station for other mobile stations served by the base station on the same time/frequency resource, where the one or more indices of the at least one preferred companion precoding vector is/are different from the one or more indices of the at least one preferred precoding vector,

transmit the one or more indices of the at least one preferred precoding vector towards the base station via an uplink channel for use by the base station to determine the at least one preferred precoding vector to communicate with the mobile station, and

transmit the one or more indices associated with the at least one preferred companion precoding vector towards the base station via the uplink channel for use by the base station to determine the at least one preferred companion precoding vector to communicate with at least one of the other mobile stations served by the base station on the same time/frequency resource.

14. The mobile station according to claim **13**, wherein the at least one processor is operable to: determine a signal quality parameter for at least two precoding vectors, wherein the signal quality parameter is a real scalar inter-cell interference indicator indicating an inter-cell spatial interference, a real scalar inter-cell interference indicator indicating a received inter-cell signal strength, a real scalar inter-cell interference indicator indicating an inter-cell signal-to-noise-ratio or a real scalar inter-cell interference indicator indicating an inter-cell signal-to- interference-and-noise-ratio, wherein said at least one processor is operable to select an index of the preferred precoding vector based on the determined signal quality parameter and showing a high received signal strength, signal-to-noise-ratio and/or signal-to-interference-and-noise- ratio, and wherein said at least one processor is operable to select an index of the preferred companion precoding vector based on the determined signal quality parameter and showing a low received signal strength, signal-to-noise-ratio, signal-to-interference-and-noise-ratio and/or inter-cell spatial interference.

15. The mobile station according to claim **14**, wherein the at least one processor is operable to determine the signal quality based on a measurement of a reference signal.

16. The mobile station according to claim **14**, wherein the mobile station is operable to select the index of the preferred

precoding vector and at least one index of an auxiliary preferred precoding vector which is reportable to the base station via an uplink channel, wherein the auxiliary precoding vector is an alternative to the preferred precoding vector if the preferred precoding vector cannot be assigned as determined precoding vector to the mobile station.

17. The mobile station according to claim **14**, wherein the mobile station is operable to report the determined signal quality parameters assigned to the one or more preferred companion precoding vectors towards the base station.

18. The mobile station according to claim **14**, wherein the mobile station is operable to: receive information about a respective threshold of the signal quality parameter which is acceptable for a precoding vector to be selected as preferred companion precoding vector at the mobile station, compare the determined signal quality parameters with the threshold, and select the index or indices of that precoding vectors as preferred companion precoding vector indices which are below the threshold.

19. The mobile station according to claim **14**, wherein the mobile station is operable to select precoding vectors from a fixed or a preset set of indexed precoding vectors for the code book, known to the mobile station.

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